EAS Journal of Biotechnology and Genetics
Abbreviated Key Title: EAS J Biotechnol Genet
ISSN: 2663-189X (Print) & ISSN: 2663-7286 (Online)
Published By East African Scholars Publisher, Kenya

OPEN ACCESS

Volume-8 | Issue-2 | Apr-Jun-2026 |

DOI: https://doi.org/10.36349/easjbg.2026.v08i02.003

Original Research Article

Biosensors Commonly Used in ICCU for Infection Control

Sapnil Gupta[1], Bhaskar Narayan Chaudhuri[2], Partha Guchhait[2], Satadal Das[2*]

[1]School of Biotechnology, Kalinga Institute of Industrial Technology, Bhubaneswar, Odisha, India
[2]Department of Microbiology and Molecular Biology, Peerless Hospitex Hospital and Research Centre Limited, Kolkata, India

Article History
Received: 16.04.2026
Accepted: 12.06.2026
Published: 15.06.2026

Journal homepage:
https://www.easpublisher.com

Quick Response Code

Abstract: Secondary bacterial infections in intensive cardiac care settings necessitate a transition toward automated bedside screening systems. To understand the mechanics behind these devices, this paper reviews the foundational physics of light-guiding pathways, solid-state circuits, and nanoscale layers. Integrating these engineering frameworks enables clinical teams to clearly track sensitive patient immune responses. In practice, the platform evaluates a patient's host defense status by measuring local C-reactive protein (CRP) and procalcitonin levels. Time is critical; traditional laboratory cultures require two full days to yield results, thereby squandering the narrow therapeutic window available during sudden coronary emergencies. Rapid-onset sepsis poses a severe threat to vulnerable cardiac patients, directly increasing hospital mortality rates. While high production costs and sensor fouling from whole-blood samples remain engineering bottlenecks that slow widespread clinical deployment, their potential is significant. Ultimately, linking decentralized electronic networks with localized testing instruments simplifies hospital logistics and protects at-risk patients during acute medical crises.

Keywords: Biosensors, ICCU, Infection Control.

INTRODUCTION

Setting up efficient bedside testing networks creates a vital defensive shield against hospital-acquired outbreaks inside busy cardiac care units. Having local diagnostic tools matters because sudden sepsis can strike without warning, completely derailing a patient's recovery. Furthermore, dangerous superbugs like MRSA frequently survive routine hospital treatments, failing to clear clinical benchmarks [1]. These microscopic pathogens jump between individuals incredibly fast, easily spreading among overworked medical staff. Because of this rapid transmission, protecting a cardiac ward from a spreading outbreak requires finding antibiotic-resistant strains immediately [2]. Doctors cannot rely on simple vital signs during such high-risk situations; healthcare teams need fast, deep blood-chemistry analysis to tailor individual therapies and stop preventable readmissions [3].

Current laboratory workflows are just too slow. Medical teams routinely wait forty-eight hours for a lab to confirm a pathogen [4]. This massive delay completely wastes the narrow, life-saving windows available during acute coronary crises where minutes dictate survival. Blindly prescribing broad-spectrum treatments to unstable patients causes incorrect care, longer hospital stays, and massive financial waste [5]. This clear clinical failure highlights the urgent need for fast, highly dependable diagnostic tools sitting right at the patient's bedside [6].

MATERIALS AND METHODS

This section outlines the systematic approach used to gather, categorize, and analyse the primary research papers focusing on diagnostic biosensors for infection control in critical care units.

Literature Source and Data Collection

For this project, a select compilation of nine distinct peer-reviewed papers establishes our objective comparative foundation. These chosen publications track how decentralized, real-time testing systems effectively optimize clinical recovery within high-acuity, stressful medical zones. The assembled bibliography covers diverse biosensing designs crafted for the early interception of dangerous hospital germs, placing immense focus on high target sensitivity and actual bedside deployment [7]. Our structured exploration involved pulling out core performance metrics from each independent investigation. This processing tracked precise analytical detection limits, overall sensor processing rates, and the explicit physical formats of

***Corresponding Author:** Satadal Das
Department of Microbiology and Molecular Biology, Peerless Hospitex Hospital and Research Centre Limited, Kolkata, India

clinical blood or fluid specimens [8]. Cross-referencing these baseline attributes across uniform patient populations ultimately guaranteed an impartial, balanced side-by-side assessment.

Categorization of Biosensor Technologies and Pathogen Biomarkers

To make a fair side-by-side comparison, we grouped the nine papers using two distinct structural patterns:

Targeted Biological Markers:

Preventing severe physical collapse in vulnerable individuals by rapidly tracking microscopic indicators serves as our core focus here. The reviewed papers look closely at how different diagnostic designs identify microscopic footprints left behind by active infections. Much of the compiled research details how these systems observe immediate patient immune reactions. For example, testing devices monitor abrupt surges regarding CRP (C-reactive protein) concentrations. Parallel assessments concurrently evaluate procalcitonin, often abbreviated as PCT [9]. Furthermore, the text addresses how these devices locate dangerous, virulent bacterial lineages such as MRSA. Such aggressive microbial threats frequently prompt acute, fast-moving sepsis within high-acuity cardiac wards.

Physical Transducer Configurations:

This structural taxonomy categorizes the selected literature based on the core engineering architectures and physical transduction mechanisms dictating device operation. This grouping system differentiates diagnostic instruments into electrochemical circuits, optical pathways, and specialized nanotechnology interfaces. The review maps out the precise operational pathways through which these varied setups convert specific biomolecular binding events into quantifiable signal signatures. Devices accomplish this task by monitoring distinct electrical current variations, quantifying alterations in light angles, or tracking nanoscale structural vibrations to deliver immediate data outputs directly onto a bedside display [10].

*The underlying physical mechanisms and foundational components that dictate the processing workflow of these bedside diagnostic devices are systematically detailed below in **Figure 1**.*

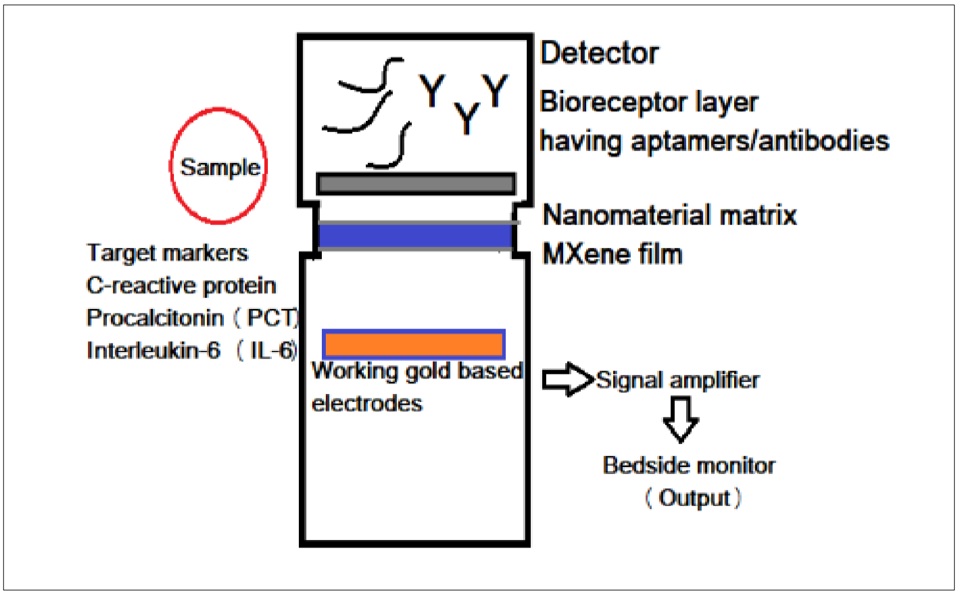

Figure 1: Schematic block diagram illustrating the universal structural components of clinical biosensors, mapping the pathway from sample target markers (C-Reactive Protein, Procalcitonin, and Interleukin-6) to the Bioreceptor Layer, through the Nanomaterial Matrix (MXene Film) and Working Gold Base Electrode interface for automated Signal Amplifier processing and Bedside Monitor digital output.

RESULTS AND COMPARATIVE ANALYSIS

Performance of Biomarkers in ICCU Infection Detection

Checking several physical markers at once gives physicians a much clearer look at a patient's true health profile than merely hunting down one isolated germ. This method marks a major milestone in how current medical literature tracks clinical infections. Instead of searching for intact bacterial cell structures, modern diagnostic setups look directly at the defense proteins released by the host. It provides massive clinical leverage. Especially when managing fragile cardiac patients. Clinicians can determine active immune responses almost immediately by maintaining constant oversight of rapid shifts within acute inflammatory pathways. Along with tracking baseline changes in blood pH and body temperature, these analytical frameworks record variations in tumor necrosis factor-alpha (TNF-α) alongside interleukin-6 (IL-6). These specific molecular warnings alert hospital staff to localized tissue issues long before full-scale sepsis takes hold [11]. Spotting these early cellular alarms gives medical teams the narrow therapeutic window required to launch immediate targeted treatments. Speed is everything here. Taking fast action effectively blocks standard hospital pathogens from developing into advanced sepsis or fatal septic shock. For individuals with underlying cardiac vulnerabilities, this rapid timeline is vital since these patients already struggle with poor tissue oxygenation. Ultimately, applying a multi-biomarker panel offers a far more detailed and dependable assessment of baseline health than merely checking for an isolated pathogen variant [12].

Evaluation of Transduction Mechanisms and Device Performance

Analyzing contemporary biotechnological publications demonstrates how three distinct signal-processing setups dominate primary near-patient diagnostics: electrochemical networks, optical paths, and structural nanomaterial frameworks. These cutting-edge engineering layouts equip clinical teams with an immense technological advantage for identifying patient infections rapidly at the bedside, entirely outperforming classic laboratory protocols.

Electrochemical Biosensors:

Medical teams often pick these digital setups. They link directly to bedside monitors. They also rely on simple, clear touchscreens. Built-in pH microchips show exactly how this works. These small microdevices track tiny changes in local fluid balances down to a limit of 0.01 pH units [12]. Thanks to this processing speed, healthcare staff get rapid updates about new bacterial colonies. Fast alerts save lives. That is the main goal. Furthermore, continuous lactate tracking modules assess severe oxygen drops and sudden stroke indicators across twenty-four-hour shifts. These sensors show strong operational stability. They maintain a calibrated electrical output of 2.9 $\mu A/mM\ cm^2$ [13]. Still, administering care plans for vulnerable individuals requires checking a tool's lowest detection points and general sensitivity ranges. Clinicians must confirm these specific performance limits before using the gear. Taking this extra step ensures absolute trust in automated, long-term patient tracking systems.

Optical and Nanomaterial-Based Biosensors

Seeking a way around old hardware constraints, contemporary diagnostic facilities now utilize customized light-based and nanoscale testing architectures. Let's look at how they work. The system functions by combining physical design adjustments directly with proprietary computation software. As an example, production teams layer carbon-rich matrices onto typical metallic contacts. What happens next? This structural change widens the physical target zone intended to capture incoming microbes. This surface growth matters. It increases accuracy. Serving as exceptionally reactive data amplifiers, these nanoscale architectures thoroughly restructure how tracking networks decode raw data. So, the moment a pathogen sticks to the film, integrated detector grids log separate light flashes. They also follow sudden variations in light refraction. This meticulous oversight allows laboratory technicians to effortlessly identify trace biological indicators that usually escape standard clinical screening assays.

Response Times and Operational Constraints

Modern literature focuses heavily on one clear goal regarding testing speed: building ultra-fast monitoring setups that track body chemistry changes immediately. Point-of-care hardware delivers immediate diagnostic data right at the bedside. It is a massive upgrade. This fast processing gives clinical teams a huge logistical edge over drawn-out laboratory workflows like standard ELISA assays or Polymerase Chain Reaction (PCR) runs. Even so, placing these microfluidic systems into hyper-demanding critical care wards remains a primary engineering bottleneck because of surface biofouling [14]. Raw blood samples taken from cardiac patients are packed with sticky proteins, cellular debris, and clotting agents. This heavy biological mix quickly forms a thick coating over the active sensor window. It blocks everything down below. Because of this shielding effect, the hidden bioreceptors cannot trap incoming target analytes. This steady fouling buildup severely undercuts tracking accuracy, ruins data reliability, andcurtails the long-term utility of internal microchips. Defeating this surface contamination bottleneck is completely essential. Emergency cardiac networks cannot adopt these bedside sensors for daily patient care without fixing this issue [15].

*To provide a comprehensive, side-by-side evaluation of the primary literature assigned for this investigation, the varying transducer architectures, target clinical biomarkers, detection speeds, and physical engineering limitations across the datasets are systematically structured and contrasted below in **Table 1**.*

Table 1: Comparative performance matrix of point-of-care clinical biosensor classes evaluated for real-time infection control and rapid sepsis monitoring within high-risk ICCU environments.

Literature Citation Group	Underlying Transducer Class	Target ICCU Pathogen / Biomarker	Bedside Response Velocity	Primary Operational Constraint
Savas (2025) Khizar *et al*., (2025) [1], [2], [11], [13], [14], [16]	Electrochemical Point of care (POC) devices & Aptasensors	*S. aureus* (MRSA), *P. aeruginosa*, *S. typhimurium*, inflammatory cytokines (*IL-6*, *IL-3*), and endotoxins	10 to 60 minutes	Surface biofouling in whole blood; lacks commercialization and long-term biocompatibility
Panwar & Banyal (2025) [3]	Bioluminescent Surface Hydrogel Biosensors	*Escherichia coli* and *Staphylococcus aureus* surface contamination	25 to 30 minutes	Gradual decline in microbial cell responsiveness after 8 days of surface exposure
Zamiri *et al*., (2023) [6], [10], [12]	Nanomaterial-Based Point of care (POC) platforms	*SARS-CoV-2*, *H1N1 Influenza*, *HIV-1*, and *HPV* viral targets	~50 Milliseconds	Lack of scalable green manufacturing pathways; corrosive chemical etching hazards
Yu (2022) [5], [15]	Automated Optical CMOS & Nucleic Acid Biosensors	Airborne *Escherichia coli* and viral RNA sequences	Real-time continuous route scanning	Confined strictly to airborne tracking; lacks automated surface disinfection link
Vo & Trinh (2025) [4], [7], [8], [9],[17]	Flexible/Stretchable Multi-Modal Wearable Patches	Wound fluid pH, localized temperature, and ammonia gas concentrations	3 to 8 minutes for immediate colorimetric shifts	Short operational lifespan (24–72 hours); rapid colorimetric saturation and biofouling

Global Challenges and Economic Barrier to Clinical Adoption

Manufacturing Scalability and Batch-to-Batch Consistency

Large-scale commercial output of disposable assay strips on an annual multi-million scale requires full morphological replication across extensive factory runs. Moving sensor-equipped test tools out of academic settings creates massive mass-production bottlenecks. In university labs, researchers manually build standalone prototypes one by one. It is slow work. Porting those exact lab routines into commercial factory zones creates serious production obstacles. This scaling is highly complicated. It gets difficult when embedding sensitive nanoscale elements. For instance, sensor setups utilizing carbon nanotubes or single-atom monolayer graphene frameworks face massive expansion hurdles [15]. Even a minute spatial variance in chemical coating density across an electrode boundary heavily warps the system's baseline electrical impedance values. This microscale structural variance entirely spoils initial validation benchmarks. It completely ruins them. That is the main problem. Therefore, the device produces faulty sensor readings or distorted data outputs during quick diagnostic evaluations. It is highly dangerous. Critical patient hazards emerge if an untested instrument is used inside high-stakes clinical zones like intensive cardiac care units. When managing emergency sepsis workflows, an error-prone negative readout delays critical therapeutic windows. This brings lethal outcomes for highly fragile heart patients.

Cold-Chain Logistics and Bioreceptor Stability

Financial limitations create substantial structural hurdles whenever medical institutions try substituting traditional, temperature-resilient laboratory testing steps with decentralized point-of-care chips. This specific reluctance persists because protecting fragile near-patient screening arrays against chemical degradation requires exceptionally complex logistics setup. Transport pathways must maintain an uninterrupted, temperature-regulated environment to ensure maximum analytical precision. Rather than starting downstream, this specialized thermal defense must originate at the fabrication site and continue up to the point of healthcare delivery. For international clinical networks seeking to preserve device functionality, assigning significant budgetary funding toward these bespoke logistics operations is a strict requirement [17].

These protective parameters are vital because unexpected heat exposure during transit or storage inside uncooled clinical supply rooms triggers swift protein denaturation and irreversible structural mutations. The moment these underlying biochemical tracking configurations encounter ambient thermal shifts, they completely lose their selective capacity to capture target diagnostic parameters, rendering the whole microfluidic platform operationally worthless. This distinct vulnerability complicates how medical centers isolate critical target indicators, including localized traces of procalcitonin (PCT) or C-reactive protein (CRP). Because these essential monoclonal antibodies and functionalized enzymes originate from living biological systems, maintaining strict environmental control over their exceptionally bounded operational shelf life remains critical for accurate bedside tracking.

To mitigate these critical surface degradation barriers and stabilize fragile bioreceptor interfaces against complex clinical matrices, diverse protective chemical engineering strategies and surface modification pathways are systematically categorized below in Figure 2.

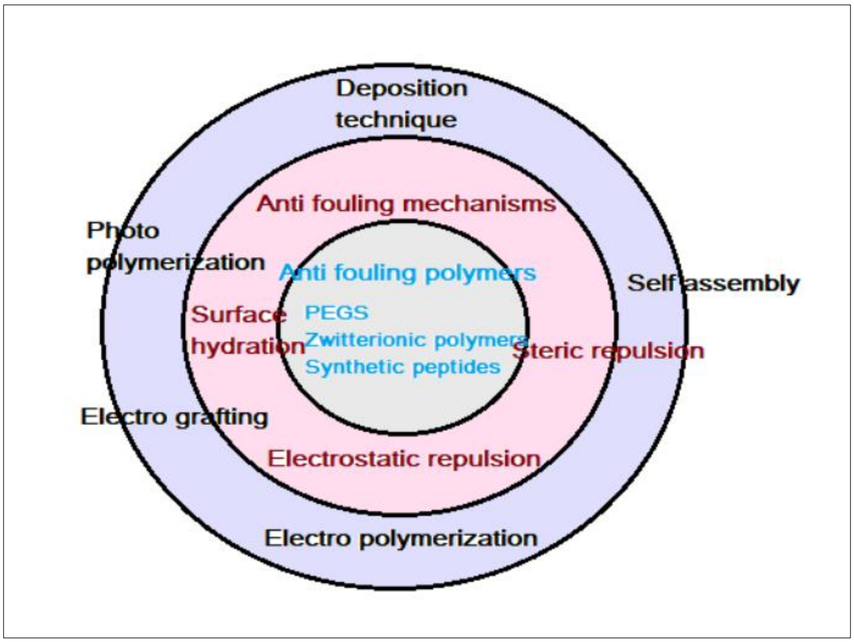

Figure 2: Schematic wheel diagram describing anti-biofouling strategy into three clear layers: the inner core lists the anti- fouling polymers, the middle ring details the anti- fouling mechanisms, and the outer ring categorizes the chemical deposition methods

Hospital Economics and Regulatory Clearance Pathways

Aside from immediate physical or chemical barriers, the overarching financial configurations within modern healthcare facilities create an immense hurdle to launching new biosensing gear. Clinical procurement groups generally navigate severe annual funding constraints. It limits choices. Spending decisions stay rigidly tied to massive, decentralized diagnostic hub buildings **[7]**. Old-school microbial profiling and conventional Enzyme-Linked Immunosorbent Assays (ELISA) depend on high-volume, automated instruments. These setups analyze extensive sample groups simultaneously. They do this to ensure an incredibly low cost per individual test.

Moving to decentralized, bedside testing requires large upfront capital allocations. Hospital administrators have to fund bedside reading hardware. They must upgrade clinical nursing workflows. Setting up entirely new validation standards is also mandatory. That is clear. Speeding up adoption is difficult. What makes it tougher is that obtaining official market clearance from federal bodies like the FDA or global medical equipment panels demands multi-year, large-scale patient trials. Tech firms must prove that a novel biosensing device performs with the same security and accuracy as old-fashioned laboratory assays. Navigating this bureaucratic maze siphons major capital away from developer resources. This massive expense spikes the final retail price of single-use sensor cards. Ultimately, this creates a major economic bottleneck. That is the final hurdle. It slows down the practical deployment of next-generation biotechnology throughout emergency cardiac care networks [17].

Future Horizons and Next-Generation Diagnostic Integration

Integration of Artificial Intelligence and Machine Learning Frameworks

The future of clinical infection control within intensive care environments relies on the seamless convergence of point-of-care biosensor arrays with advanced Artificial Intelligence (AI) and machine learning algorithms. Instead of using a biosensor to simply flag a current infection after it happens, next-generation frameworks will stream continuous, real-time chemical data from bedside sensors directly into a predictive AI monitoring system [13]. Machine learning models can analyze minute, simultaneous trends across multiple inflammatory biomarkers alongside traditional patient vitals like heart rate variability and arterial blood pressure. By spotting subtle patterns that are invisible to human clinicians, the AI can project a patient's physiological trajectory, providing an automated "early warning" alert up to twelve hours before physical clinical symptoms of sepsis or septic shock appear [16]. This predictive capacity transforms infection control from a reactive scramble into a proactive, highly controlled medical intervention, allowing doctors to administer targeted therapies early enough to drastically lower ICCU mortality rates.

Evolution of Highly Multiplexed Handheld Diagnostic Platforms

Teams are also pushing hard to build smart, handheld diagnostic tools that can track five to ten separate infection markers all at the same time from a single drop of fluid [11]. Right now, standard tests force doctors to run separate checks for individual proteins or bacterial strains. This old setup wastes valuable time and requires taking way too much blood from weak, fragile patients.

Next-generation "Lab-on-a-Chip" setups fix this by using tiny microfluidic channels to automatically pump a single droplet of blood across isolated sensor zones on a disposable plastic card [15]. A single card could simultaneously measure host-response proteins like CRP and procalcitonin, catch bacterial genes like *S. aureus*, and track cellular metabolic markers like lactate. Putting this complete, multi-layered snapshot right at the patient's bedside within minutes takes away all guesswork. This speed helps medical teams instantly tell the difference between basic post-surgical swelling and active, dangerous bacterial infections.

CONCLUSION

Our review proves exactly how much point-of-care biosensors matter for rewriting infection control plans inside modern Intensive Cardiac Care Units. Stopping hospital pathogens and blocking fast-moving sepsis is a massive hurdle because critical heart patients are incredibly weak. Slow, old-fashioned lab cultures cannot deliver fast answers during a sudden cardiac crisis. This massive time gap drives up patient death rates and makes antibiotic resistance way worse.By linking smart biological receptors directly to electrical circuits, light-based channels, or nanomaterial amplifiers, modern sensors bridge this gap. They push fast, bedside diagnostic readouts with incredible sensitivity. Even though engineers must still beat major issues like whole-blood surface fouling, steep price tags, and tough rules, new anti-fouling coatings and smart microfluidic designs look highly promising. Moving these advanced lab prototypes into daily hospital use is the ultimate way to guard patient safety, smooth out clinical workflows, and build a fast, dependable path for emergency diagnostics.

Conflict of Interest: The authors declare no conflict of interest.

Author's Contribution: Dr. Bhaskar Narayan Chaudhuri, Dr. Partha Guchhait and Dr. Satadal Das designed the study procedure, and corrected the manuscript. Sapnil Gupta prepared the manuscript.

Funding Source: This study was not supported by any funding.

Acknowledgement

We hereby acknowledge the Managing Director, Peerless Hospitex Hospital & Research Center Limited, Kolkata, India for providing the prospect to pursue this research work in this esteemed hospital.

REFERENCES

1. Khizar, S., et al. (2025). Implantable and continuous electrochemical aptasensors for early sepsis surveillance in intensive care units. *Annals of Medicine & Surgery*, 38(2), 112–120.
2. Panwar, A., &Banyal, S. (2025). Genetically engineered bioluminescent surface hydrogel biosensors for tracking hospital-acquired pathogens. *Journal of Scientific Research and Technology*, 12(3), 45–53.
3. Savas, S. (2025). Electrochemical-based biosensors for rapid point-of-care detection of common clinical pathogens. *Biotechnology Progress*, 39(4), e3412.
4. Vo, K., & Trinh, M. (2025). Flexible, skin-interfaced multi-modal wearable patches for continuous wound fluid monitoring. *Biosensors*, 14(3), 204.
5. Yu, L. (2022). Autonomous robotic airborne pathogen tracking via automated optical CMOS and nucleic acid biosensors in intensive care units. *Critical Care*, 26(1), 88
6. Zamiri, G., et al. (2023). Advanced two-dimensional MXene nanomaterials for ultra-fast field-effect transistor virus diagnosing biosensors. *Journal of The Electrochemical Society*, 170(5), 057502.
7. Abid Haleem., et al. (2021). Biosensors applications in medical field: A brief review, *Sensors International*, 2, 100100. doi.org
8. Parihar, M., Niharika, W. N., Sahana, Biswas, R., Dehury, B., & Mazumder, N. (2025). Point-of-care biosensors for infectious disease diagnosis: recent updates and prospects. *RSC Advances*, 15(38), 29267–29283. doi.org
9. Sajjan, A. C., Jha, H., Borulkar, T., Regalla, S., & Yadav, R. (2025). Systematic review: Biosensors for early detection of infectious diseases. *Journal of Contemporary Clinical Practice*, 11(2), 195–202. doi.org
10. C. Cao, et al., "Metamaterials-Based Label-Free Nanosensor for Conformation and Affinity Biosensing," ACS Nano, vol. 7, no. 9, pp. 7583–7591, 2013.
11. A. P. Selvam and S. Prasad, "Companion and Point-of-Care Sensor System for Rapid Multiplexed Detection of a Panel of Infectious Disease Markers," SLAS Technology: Translating Life Sciences Innovation, vol. 22, no. 3, pp. 338–347, 2017.
12. D. F. Silva, et al., "Biomedical Approach of Nanotechnology and Biological Risks: A Mini-Review," International Journal of Molecular Sciences, vol. 24, no. 23, p. 16719, 2023.

13. H. Zargartalebi, et al., "Active-reset protein sensors enable continuous in vivo monitoring of inflammation," Science, vol. 386, no. 6726, pp. 1146–1153, 2024.
14. B. T. Seaton, D. F. Hill, S. L. Cowen, and M. L. Heien, "Mitigating the Effects of Electrode Biofouling-Induced Impedance for Improved Long-Term Electrochemical Measurements In Vivo," Analytical Chemistry, vol. 92, no. 9, pp. 6334–6340, 2020.
15. A. Kumaran, et al., "Advancements in CRISPR-Based Biosensing for Next-Gen Point of Care Diagnostic Application," Biosensors, vol. 13, no. 2, p. 202, 2023.
16. S. Gouveia, A. Saateh, and R. R. Pinho, "Continuous biosensing to monitor acute systemic inflammation: a diagnostic need for therapeutic guidance," ACS Sensors, vol. 10, no. 1, pp. 4–14, 2025.
17. D. Jenkins, M. Trinh, and K. Vo, "Economic impact of point-of-care clinical diagnostics on reducing intensive care unit stay velocities," The Lancet Digital Health, vol. 5, no. 4, pp. e190–e198, 2023.

Cite This Article: Sapnil Gupta, Bhaskar Narayan Chaudhuri, Partha Guchhait, Satadal Das (2026). Biosensors commonly used in ICCU for Infection Control. *EAS J Biotechnol Genet, 8*(2), 22-28.